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POTATO FLAKES

A NEW FORM OF DEHYDRATED MASHED POTATOES

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III. ESTIMATED COMMERCIAL COST

April 1956

POTATO FLAKES. A NEW FORM OF DEHYDRATED MASHED POTATOES
III. ESTIMATED COMMERCIAL COST

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INTRODUCTION

A process for preparing a dehydrated mashed potato in flake form, capable of reconstitution to a product having good flavor, color, and texture, has been described (1,2,3). A double-drum drier was used in this work. However, it was later found that a single-drum drier of the type employed in making potato flour is preferable in several respects. This circular presents estimated costs for the commercial production of flakes on single-drum driers, and shows the effect of the price and solids content of the potatoes used on the cost of the product.

PILOT-PLANT OPERATIONS

The basic engineering data for making cost estimates for commercial operation were obtained in an integrated pilot plant as shown in Figure 1. For convenience abrasion peeling was used followed by hand trimming. The trimmed potatoes were sliced into 5/8-in. thick slabs, washed to remove free starch, and precooked at 165°F for 15 min. The precooking step is shown in Figure 2. After further cooking in live steam for about 20 min. the slices were riced; an antioxidant and a sulfite solution were incorporated batchwise in a mixer as shown in Figure 3. Figure 4 shows the feed side of the single-drum unit. The mash is fed into a trough on top of the drier (barely visible at the top of the picture) and is picked up by the first applicator roll which deposits a thin layer on the heated drum. The second, third, and fourth applicator rolls, which are kept covered by a layer of mash during the entire operation, deposit additional mash as the drum rotates, building up a dense sheet. Fresh mash, or excess mash removed mechanically from the first roll, is continuously added to the other three rolls.

Increased sheet density means lower packaging costs. A dense sheet also absorbs water slowly, thereby reducing any tendency for cells to rupture on reconstitution. One of the advantages of the single drum is the dense sheet obtained, as contrasted with the more porous nonuniform sheet produced on the double drum. A further advantage is that potatoes with a solids content as high as 22% can be dried directly to produce a dense sheet. With a double-drum drier, potatoes containing over 20% solids must be diluted with water (2).

A scoring device improvised to break the sheet into flakes of a desirable size for packaging is shown in Figure 5. This consists of two wooden rolls, one covered with sponge rubber and the other with coarse wire screening, running in contact with each other.

* *A laboratory of the Eastern Utilization Research Branch, Agricultural Research Service, U. S. Department of Agriculture.*

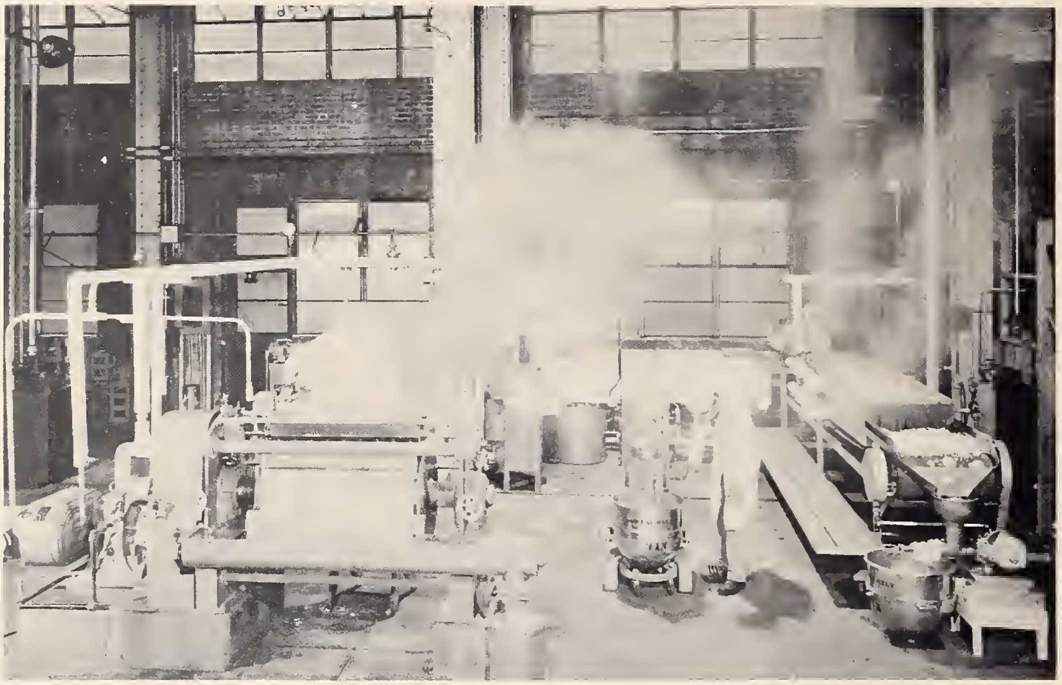

Figure 1. General view of pilot-plant production of potato flakes.

Figure 2.

Precooking the sliced, peeled potatoes.

The drum drier used in the pilot plant was manufactured by the Overton Machine Company,* Dowagiac, Michigan. The drum is 2 ft in diameter and 3 ft long and has a capacity of approximately 275 lb of mash per hour when operating with high-solids potatoes and drying to about 4.5% moisture. It is felt that the size of this unit permits scaling up performance data to commercial size, e.g., drum 4 ft in diameter and 10 ft long.

BASIC ASSUMPTIONS FOR COST ESTIMATION

The projected commercial process is substantially that described earlier (2) except for the substitution of a single-drum for a double-drum drier. Figure 6 is a suggested flow sheet. It is diagrammatic and should not be taken to represent the actual arrangement of equipment. The numbers correspond to those on the Equipment Summary, Table I. The following operating conditions are assumed for purposes of cost estimation and will apply in general, although minor modifications may be required with changes in season and in potato composition or variety.

"High-solids" potatoes are assumed to contain 22% solids as typified by Russet Burbanks grown in Idaho. Excellent flakes have also been made from Red River Valley Cobblers of 22% solids. "Low-solids" potatoes are taken as containing 18.5% solids, and are exemplified by Russet Burbanks, Green Mountains, and Katahdins, all of which are grown in Maine, and yield a good product. The range of solids content can be that represented by "field run."

Provision has been made in the estimate to condition potatoes for 11 days at 70°F to reduce their sugar content. Potatoes fed to the drier should not contain more than 3% total sugars on a dry solids basis. A factor of safety is provided by the precooking step which removes some sugar.

The potatoes are scalded at 140°F in 22% lye for 4 min. This low-temperature lye peeling method was developed at the Western Utilization Research Branch, U. S. Department of Agriculture, Albany, California, to avoid surface cooking of the potato. An overall loss of 28% is assumed on peeling, trimming, precooking and spillage. If small culls are used, this loss will of course be increased.

Steam peeling is not recommended as the unavoidable cooking of tissue adjacent to the skin may vitiate the benefits of the precooking step which follows.

Slicing to 5/8-in. thick slabs is done in a conventional slicer, superficial starch being removed with water sprays during slicing. The potatoes are precooked at 155°F for 15 min with a belt loading of 10 in., then cooked in atmospheric steam for 20 min with slices about 3 deep.

* *Mention of company name does not imply that it is recommended or endorsed by the USDA over others not mentioned.*

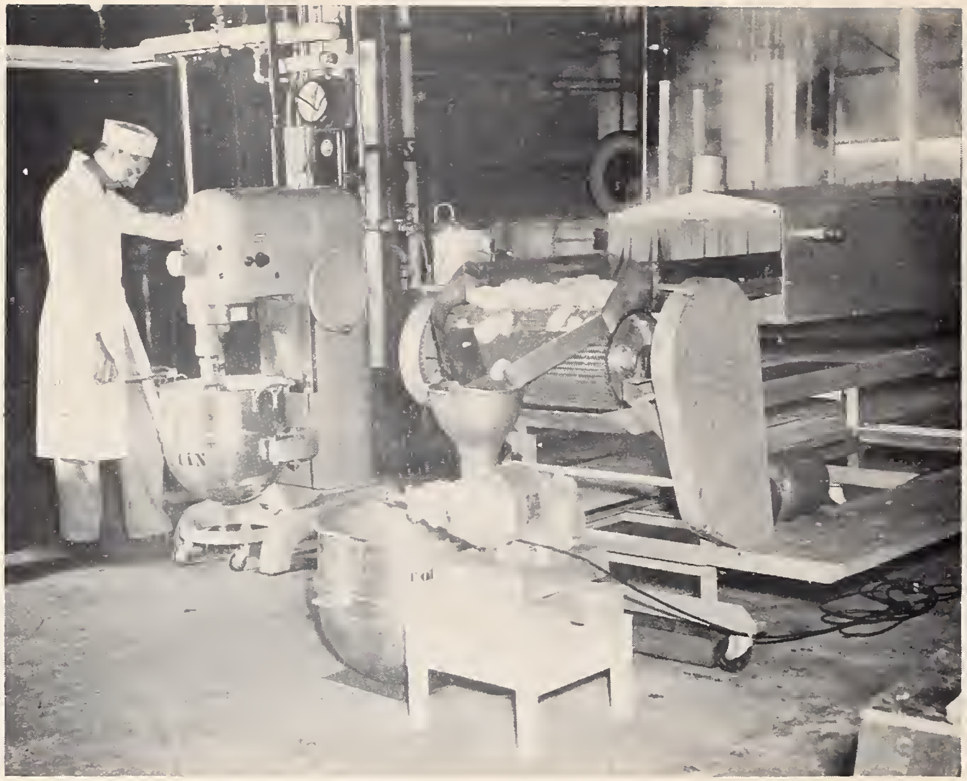

Figure 3. Mashing of cooked slices and incorporation of additives.

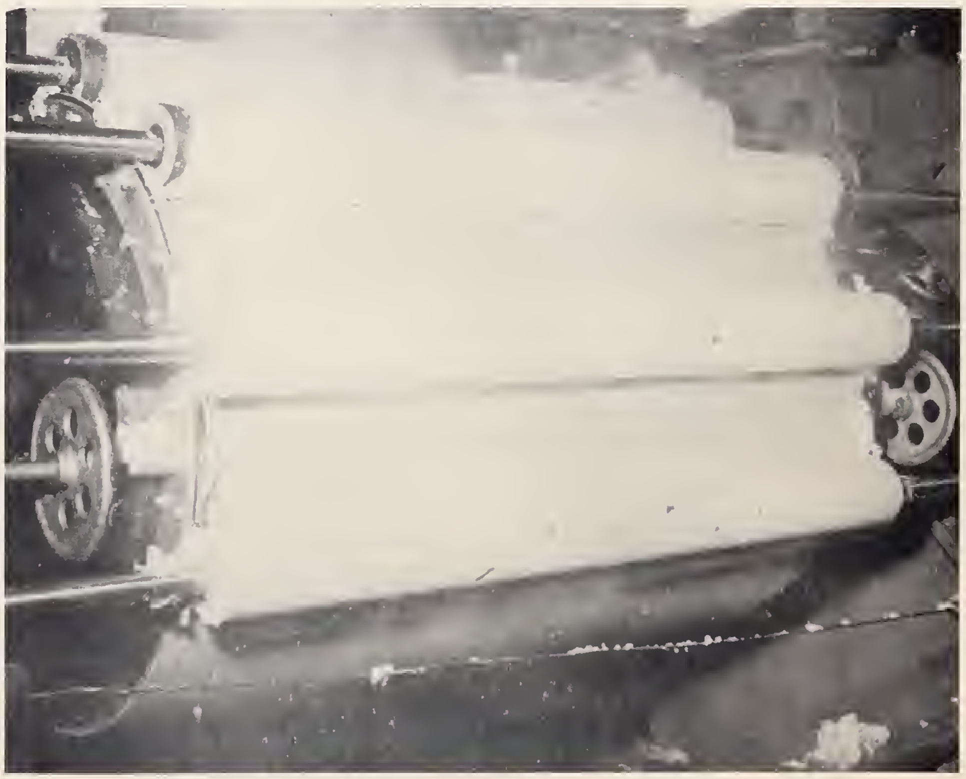

Figure 4. Wet mash side of the single drum drier showing applicator rolls.

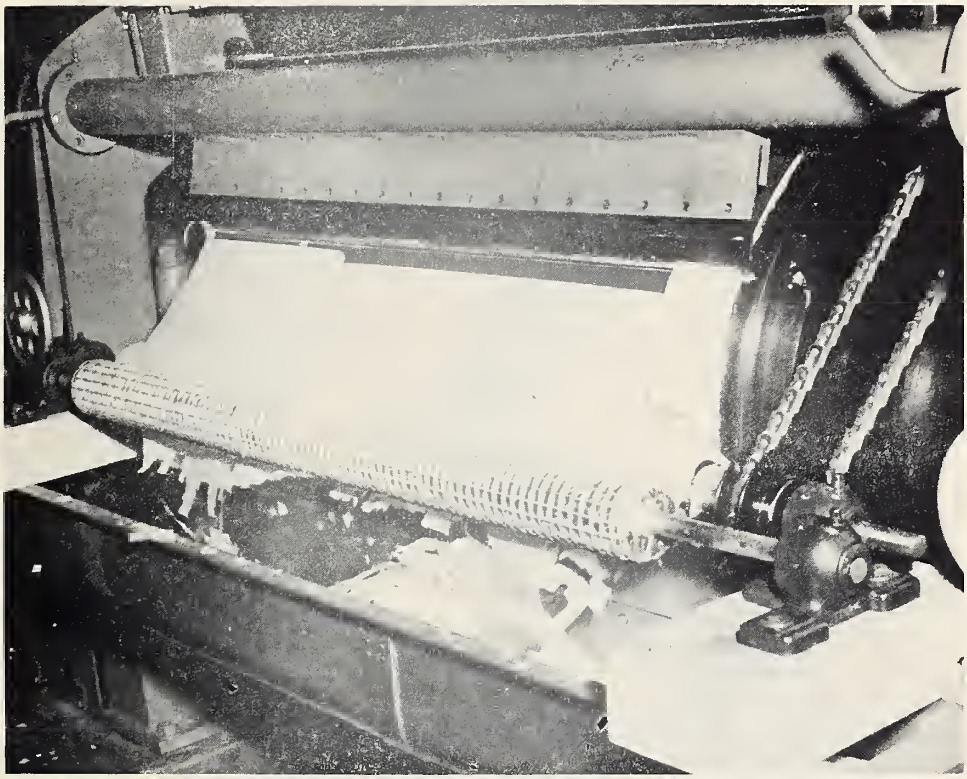

Figure 5. Product side of drier showing improvised sheet breaker.

The cooked potatoes are riced through 1/4-in. diameter holes. This is preferred to mashing between rolls as it assures a uniform sheet on the drier drum. Additives are incorporated in a pug- or ribbon-type mixing conveyor. A sulfite solution is added to give 400 ppm SO_2 in the mash. (This results in a level of about 200 ppm in the flakes.) The solution contains 2.5% $NaHSO_3$ and 7.5% Na_2SO_3 by weight and is added at the rate of 0.79 cc of solution per pound of mash. The other additive is an antioxidant, Tenox VI* which is a mixture of butylated hydroxy anisole, butylated hydroxy toluene, citric acid, glycerides, and propylene glycol. Tenox VI can be emulsified with water with vigorous agitation. A stock solution containing 24.7 g of antioxidant per liter is added at the rate of 3 cc per pound of mash. This is equivalent to 0.075% antioxidant (0.0075%BHA) in the product.

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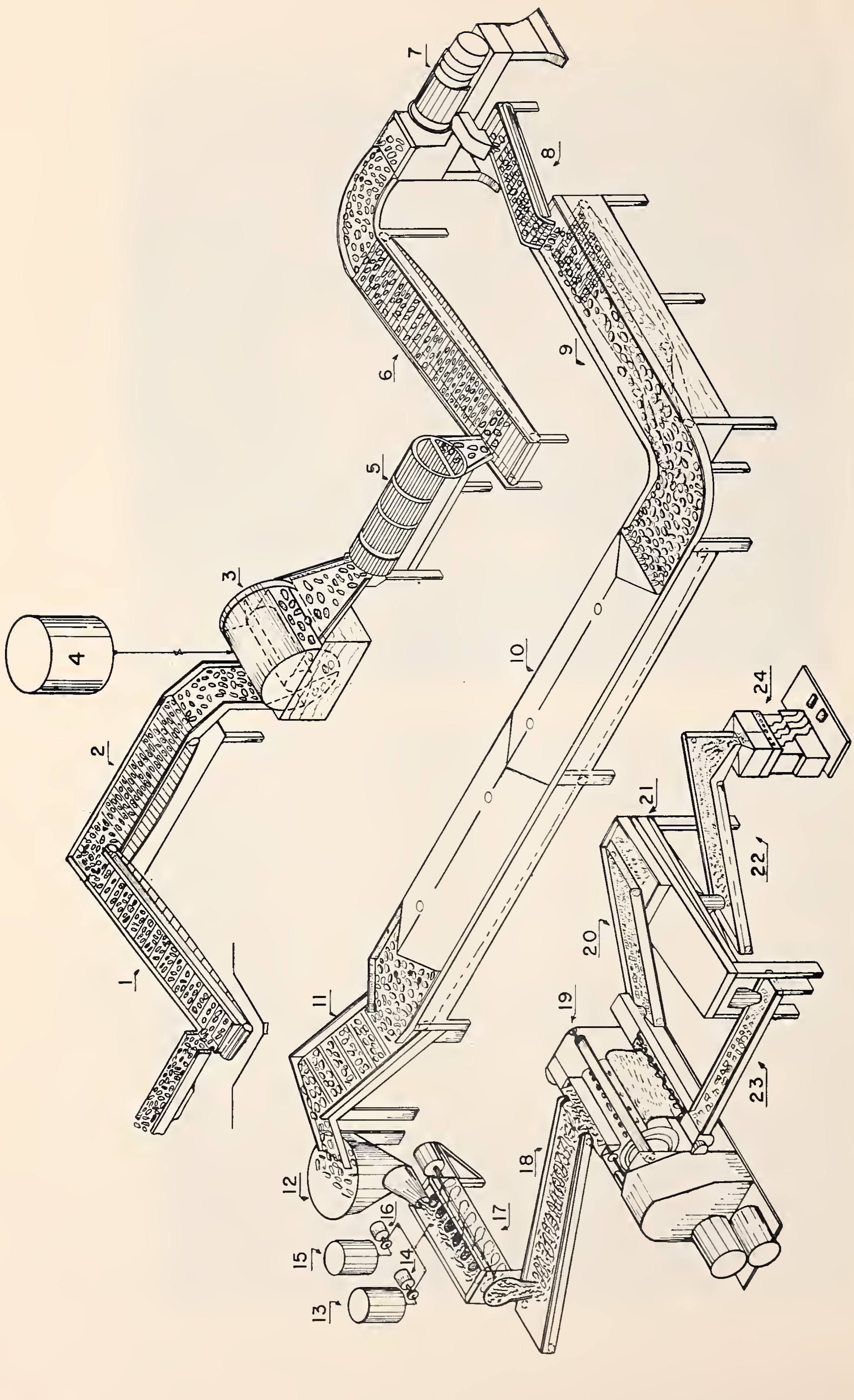

Figure 6. Flow Sheet.

Table I

EQUIPMENT SUMMARY

(Based on 18.5% Solids Potatoes)

1. ELEVATOR
Must handle 4,528 lb of potatoes per hr (received by flume from the conditioning room) and elevate them to the scanning belt. All steel slats carried by steel chain. — $2,500.

2. SCANNING BELT
Handles 4,528 lb of potatoes per hr. Slow-speed belt with side rails. Permits debris removal. (Potatoes grown in some soils may require a washer between Items 2 and 3.) — 1,030.

3. LYE PEELER
Rotary type with variable-speed drive and external heater. Handles 4,528 lb of potatoes per hr. — 3,850.

4. LYE MAKEUP TANK
Steel tank, dished head, with jacket, agitator, and transfer pump. — 740.

5. WASHER
Rotary type rod washer with spray heads and water at 60 gpm and 175 psig. Must remove skins and eyes from 4,528 lb of potatoes per hr from the lye peeler. — 3,790.

6. TRIMMING & INSPECTION BELTS
Consists of four rubber belts. One belt handles the potatoes from the washer, another mounted directly below handles the trimmed and inspected potatoes. Two narrow belts mounted on each side of the above belts carry away the waste. Must handle 3,396 lb of peeled potatoes per hr. — 3,880.

7. SLICER
Must cut 3,396 lb of peeled potatoes per hr into slices 5/8-in. thick. — 1,750.

8. ELEVATOR
Rubber belt with cleats and side rails. Must handle 3,396 lb of sliced peeled potatoes per hr. — 1,410.

9. PRECOOKER
Wood tank with aluminum lining, provided with cleated rubber elevator belt and side rails, submerged stainless steel wire mesh belt and elevator discharge belt. Includes circulating pump, capacity 100 gpm. Heated with live steam and provided with temperature controller. Operates at 155°F with a holding time of 15 min. Must handle 3,396 lb of sliced peeled potatoes per hr. — 5,600.

10. COOKER
Galvanized iron shell with fabric seals at open ends. Provided with stainless steel wire mesh belt extending beyond ends of shell for feed and discharge. Operates in live steam at atmospheric pressure with a holding time of 20 min. Must handle 3,305 lb of sliced peeled potatoes per hr, loaded on the belt at three slices thick. — 11,600.

11. ELEVATOR
Rubber belt with cleats and side rails. Must handle 3,305 lb of cooked sliced potatoes per hr. — 1,920.

12. RICER
Must rice 3,305 lb of cooked 5/8-in. thick sliced peeled potatoes per hr, through 1/4-in. diameter holes. — 2,920.

13. SULFITE TANK
Made of #316 stainless steel with hand hole in cover. — 240.

14. METERING PUMP
Must pump 0.56 gph of sodium sulfite solution. Stainless Steel. — 490.

15. ANTIOXIDANT TANK
Carbon steel tank with agitator. — $ 280.

16. METERING PUMP
Handles 0.87 gph of antioxidant. — 490.

17. MIXER
Stainlesa steel pug-mill-type mixer, with conveying and breaker blades. Must thoroughly mix riced cooked potatoes with sulfite solution and antioxidant. Must handle 3,305 lb of riced potatoes per hr. — 3,350.

18. CONVEYOR
Rubber belt with cleats and side rails. Must handle 3,305 lb per hr of riced potatoes containing sulfite solution and antioxidant. (Not required if preceding operation carried out on floor above.) — 1,390.

19. TWO SINGLE-DRUM DRIERS
Cast-iron rolls, 4 ft in diameter by 10 ft long with auxiliary rolls and variable-speed drive and provided with discharge breaker. Must dry discharged product to 4.5% moisture. — 43,500.

20. ELEVATOR
Rubber cleated belt with side rails. Must handle 632 lb of product per hour. — 1,620.

21. VIBRATING SCREEN
Two-mesh single deck wholly enclosed vibrating screen. Stainless steel screen and contact parts. — 1,620.

22. Part of packaging equipment. See Item 24e.

22A. Two covered aluminum bins located above filling equipment, each holding 1/2-hour's production of flakes (not shown in drawing). — 500.

23. SMALL CONVEYER
Returns overs to process. — 910.

24. PACKAGING
Product packed in trilaminate bags. Laminate consists of 0.001-in. polyethylene, 0.00035-in. aluminum, and 30-lb bond paper. Equipment consists of:

   a. Trilaminate bag-making machine from printed roll stock. Makes bags, fills weighed amount of product in bags, and seals. — $19,000.

   b. Conveyor, 2 bags placed in carton by hand. — 1,120.

   c. Carton-sealing machine. — 5,000.

   d. Conveyor, 24 cartons placed in shipping case by hand and sealed. — 1,210.

   e. Conveyor, flakes to packaging machine. — 900.

   27,230.

RIVER-WATER PUMP

Centrifugal pump, 125 gpm at 50-ft head, housed, for fluming potatoes. — 1,590.

124,200.

As previously reported, double-drum driers can be used to give a satisfactory flake (1,2,3). Single-drum units with applicator rolls are preferable for reasons mentioned above. Two units are required which at an evaporative rate of 10.5 lb of water per hr per sq ft, correspond to a total daily output of finished flakes of about 18,800 pounds from high-solids potatoes and 15,000 pounds for low-solids potatoes. The drums are operated at about 2 rpm using 100 psi of steam. Approximately 1.8 lb of steam are required for each pound of water evaporated.

Pilot plant experience has shown that a fine-grain cast-iron drum can be used with steel applicator rolls. Although earlier experiments were conducted with chrome-plated drums there has been no evidence of iron contamination from an uncoated cast-iron drum. It may be desirable however, to chrome-plate the applicator rolls since the wet mash remains on these for a longer period and may pick up small amounts of iron.

The relatively mild cooking conditions used and the coarse (1/4-in.) holes of the ricer are designed to maintain good texture in the product. These conditions may sometimes cause a few small lumps of mash to be deposited in the sheet on the drum. Such lumps are effectively removed by locating a wiper blade at the lowest point of the drum and parallel to the drum axis. A 1/8-in. Teflon* blade adjustable to clear the drum surface by about 1/16 in. will remove the lumps without disturbing the moist sheet.

The dried sheet can be scored or broken by passing it between two rolls operating at the same surface speed as that of the drum. One of the rolls should be soft rubber e.g., sponge rubber covered with "dam" rubber, and the other can be covered with a heavy 2-mesh wire, e.g., "hardware cloth." Further breaking will result if the blades of the discharge screw conveyor are serrated. The sheets should be broken into pieces small enough to keep package bulk low, yet large enough to avoid excess cell rupture with impairment of texture. A good compromise is a size which will just pass a 2-mesh screen. Overs from the screen can be returned to the screw conveyor which discharges from the drier where they will eventually be broken to the desired size. Ordinarily all material passing a 2-mesh can be packaged as product. It is not necessary to screen out the fines as only a small amount are formed. The bulk density of the noncompacted product from high-solids potatoes will be about 12 lb per cu ft and from low-solids potatoes about 9 lb per cu ft.

ESTIMATED COSTS FOR FACTORY OPERATIONS

It is scarcely to be hoped that any combination of assumptions will correspond to actual conditions in a potential manufacturer's plant. The assumptions made here are purposely chosen to give a "cost-to-make" figure higher than would result in actual practice. A fairly detailed cost estimate is given for a plant producing approximately 15,000 lb per day of flakes at 4.5% moisture using potatoes at 18.5% solids priced at $1.14 per 100 lb.

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Since the price of potatoes will vary widely from year to year and throughout the season, and since solids in the potato have a significant influence on costs, the effect of these two factors on the principal cost items is given. The plant is assumed to operate 24 hours a day, 6 days a week, 200 operating days per year. Since potato-flake production would probably be initiated in a plant already processing potatoes into other forms, the availability of storage and conditioning facilities as well as steam and building space is assumed. Rent for these facilities, however, is charged against flake production. Allowance for this item thus appears as an operating cost instead of as fixed investment. It is further assumed that new equipment will be used throughout the plant and liberal allowances have been made for engineering fees and equipment erection. Obviously in many cases plant equipment will be available, depreciation on which is partially or completely charged off. In some plants in Idaho suitable single-drum driers are available for flake production, thus effecting a significant reduction in the estimated equipment figure. Single-drum driers are frequently available in used equipment markets and the single-drum units can have applicator rolls installed in local shops. Other economies will at once be apparent to the potato processor.

Table I is an equipment summary, Table II shows capital costs, and Table III is a cost sheet. Table IV shows the effect of potato prices and solids on manufacturing costs.

Processing: It is apparent from the foregoing that a plant producing about 15,000 lb per day of potato flakes packaged for retail distribution, and using 18.5% solids potatoes costing \$1.14 per 100 lb can make the product at approximately \$0.32 per lb or about \$0.12 per package containing two 4-person servings.

As long as low-solids potato prices remain below about \$1.68 per 100 lb it should be possible to produce potato flakes at a cost permitting retail sale at about the current price of competitive dehydrated mashed potato products and still realize an adequate return on the investment. Undoubtedly, with increasing competition the price of dehydrated mashed potato products will decline. It is believed, however, that the inherently simple process of flake manufacture will keep flakes in a favorable pricewise position.

Packaging: One of the advantages of the flake process is that the product can be dried directly to 4.0 to 4.5% moisture in one operation in a matter of seconds. Off-flavors arising from nonenzymatic browning during storage are retarded in this moisture range. Hence for good keeping properties the package should include an effective moisture barrier. For purposes of cost estimation a package has been assumed to consist of a cardboard carton containing two heat-sealed envelopes with enough flakes in each to yield 4 servings on reconstitution. These envelopes are 6 by 7 in. and consist of a polyethylene-aluminum foil-bleached Kraft laminate. This is an expensive package but would seem justified to preserve as long as possible the initial good flavor. No storage tests have been made in this package. However, storage tests with the product containing antioxidant, packed in tin cans in air, have shown it to be still acceptable in flavor after 6 months' storage at room temperature.

Such flavor changes as occurred in these samples were absent when the samples containing antioxidant were also nitrogen packed. Tests are still in progress. These samples were reconstituted with water, milk, and butter as would typically be done in the home, and evaluated by a trained taste panel.

Marketing the product on the basis of servings rather than on actual weight in the package would give the processor of low-solids potatoes an advantage, for flakes from such potatoes require more liquid on reconstitution; hence less flakes need be used per serving. For example, flakes made from western-grown Russet Burbanks of about 22% solids content require 4-3/4 parts of liquid per part of flakes to form a good mash. The same variety of potatoes grown in the East and having 18-1/2% solids require 5-1/2 parts of liquid per part of flakes to yield a mash of the same consistency. The net result is that a package containing sufficient flakes for 4 servings would contain about 90 g if made from low-solids potatoes and about 100 g if made from high-solids potatoes. This advantage partly compensates for the higher raw-material requirements of flakes made from low-solids potatoes. Obviously the net weight in the package must appear on the label.

Bulk Packaging: Alternatively, the product might be bulk-packed in fiber drums containing about 100 lb each for institutional use or for repackaging under a distributor's label. The cost to make per pound of flakes, using 18.5% solids potatoes at $1.14 per 100 lb would then be decreased from $0.324 to $0.239. The effect of varying solids content and price of potatoes on the cost to make the bulk-packaged product is shown in Table V.

Table II

CAPITAL COSTS

Equipment, manufacture	$124,200
Equipment erection	40,800
Instrumentation	1,300
Pipe and ductwork, materials	19,300
Piping and ductwork, erection	13,500
Power, installed	4,700
Insulation	300
Freight on equipment	2,500
Contingencies	29,100
Engineering fees	43,600
Contractors' fees	11,600
Total fixed capital	290,900
Working capital	328,500
Total capital	619,400

Table III

COST SHEET

	Cost per day	Cost per lb
I. Prime cost		
Materials		
108,672 lb potatoes, 18.5% solids, at $1.1375/100 lb	$1236.14	$0.0816
Other	105.30	0.0069
Total	1341.44	0.0885
Labor cost	697.60	0.0460
Total prime cost	2039.04	0.1345
II. Indirect materials		
Trilaminate for bags for flakes	795.86	
Cartons for bags	620.89	
Shipping cases	200.29	
Glue and supplies	5.00	
Total indirect materials	1622.04	0.1070
III. Factory overhead		
Indirect labor		
Supervision	73.00	
Watchmen, yardmen	13.14	
Mechanics, etc.	32.00	
Office help	24.70	
Truck operator	3.33	
Total indirect labor	146.17	0.0096
Indirect Expense		
Fixed		
Insurance, public liability and fire	14.54	
Taxes	29.09	
Interest on fixed capital	72.72	
Depreciation	145.45	
Total fixed indirect expense	261.80	0.0173
Nonwage payments		
Social security	12.32	
Workmen's compensation	9.82	
Unemployment insurance	48.09	
Total nonwage payments	70.23	0.0046
Utilities		
Process power	32.11	
Process steam	105.57	
Process water	13.43	
Total utilities	151.11	0.0099
Miscellaneous		
Process maintenance, repairs, and renewals	87.27	
Gasoline	3.90	
Factory supplies	13.09	
Waste disposal	33.25	
Miscellaneous factory expense	10.00	
Rent, conditioning building	25.50	
Rent, processing building	93.64	
Rent, boilers	21.92	
Rent, miscellaneous	6.90	
Total miscellaneous	295.47	0.0195
Total indirect expense	778.61	0.0513
IV. Total factory overhead	924.78	0.0609
V. Factory cost	4585.86	0.3024
VI. Interest on working capital	67.51	
VII. Research and development expense	128.84	
VIII. Administration and general expense	130.64	
IX. Cost to make	4912.85	0.3241

Table IV

EFFECT OF POTATO PRICE AND SOLIDS CONTENT ON MANUFACTURING COSTS IN RETAIL PACKAGING

Potatoes per 100 lb	$.60	$.60	$1.14	$1.14	$1.68	$1.68
Solids content	18.5%	22.0%	18.5%	22.0%	18.5%	22.0%
Fixed capital	$290,900	$332,900	$290,900	$332,900	$290,900	$332,900
Working capital	$279,900	$314,900	$328,500	$365,800	$377,600	$417,200
Total capital	$570,800	$647,800	$619,400	$698,700	$668,500	$750,100
Cost of potatoes per lb of product	$0.0430	$0.0362	$0.0816	$0.0686	$0.1204	$0.1013
Cost to make per lb of product	$0.285	$0.257	$0.324	$0.289	$0.364	$0.323
Production, lb per year	3,031,600	3,776,200	3,031,600	3,776,200	3,031,600	3,776,200
Cartons per day (8 servings, 2 pkg)	40,058	45,170	40,058	45,170	40,058	45,170
Cost to make, per carton	$0.108	$0.107	$0.123	$0.121	$0.138	$0.135

Table V

EFFECT OF POTATO PRICE AND SOLIDS CONTENT ON MANUFACTURING COSTS IN BULK PACKAGING

Potatoes per 100 lb	$.60	$.60	$1.14	$1.14	$1.68	$1.68
Solids content	18.5%	22.0%	18.5%	22.0%	18.5%	22.0%
Fixed capital	$245,300	$249,500	$245,300	$249,500	$245,300	$249,500
Working capital	$191,600	$203,600	$240,100	$254,400	$289,200	$305,800
Total capital	$436,900	$453,100	$485,400	$503,900	$534,500	$555,300
Cost of potatoes per lb of product	$0.0430	$0.0362	$0.0816	$0.0686	$0.1204	$0.1013
Cost to make per lb of product	$0.199	$0.1701	$0.239	$0.203	$0.278	$0.236
Production, lb per year	3,031,600	3,766,200	3,031,600	3,766,200	3,031,600	3,766,200
Cartons per day (8 servings, 2 pkg)	40,058	45,170	40,058	45,170	40,058	45,170

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